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Description of Certain Optical Stores which have been Captured from the Enemy.

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Read and discussed 8th November, 1917.

THE optical instruments* to be exhibited this evening have been captured at different times and at different places, and are probably a fairly representative collection of the instruments employed by the Central Empires. Nearly all of them are used in connection with Artillery.

I propose firstly to give a very general idea of what instruments are required and how they are employed ; secondly to describe each instrument in fairly full detail ; and then to make a few general remarks.

I.

A battery will generally be so sited that it cannot see the target it is to engage. The range and direction of the target from the battery can be obtained in several ways. For example, they can be measured from a map, or an observer may be placed in such a position that he can see both the battery and the target. In the latter case the observer will, by means of instruments, measure the ranges from his position to the target and to the battery, and also take the angle between the lines from his position to the battery and to the target (Fig. 1). The triangle " Target, Observer, Battery " can then be solved, and the range of the target given to the battery. If the dial sights in the battery are set at the angle made by the lines from the battery to the target and to the observer, and the sights are then laid on the observer's instrument or director, the axes

* These instruments are on view at the Imperial College of Science and Technology, South Kensington. Applications for permission to examine them should be made to Prof. F. J. Cheshire.

of the guns will point in the direction of the target. The director may not form a very good object to lay on, and usually a more conspicuous object, called an auxiliary point, is used for the purpose. The gun having once been layed on the director, the dial sight is layed on the auxiliary point by traversing the upper portion of it and not moving the gun. The azimuth reading of the dial sight is noted, and the sight is set at that reading and layed on the auxiliary point for all successive rounds. The observer is usually placed either on a flank of the battery, or as near to the target as possible, the guns being very much farther away from it. The place from which observations are carried out is known as the forward observation post and must be as inconspicuous as possible. It often consists of a cell having an opening only a few inches high. This necessitates all the observing instruments being very small in size. A compass is usually fitted to directors, so that parallel lines of sight may be obtained by their means, even if the directors cannot see one another.

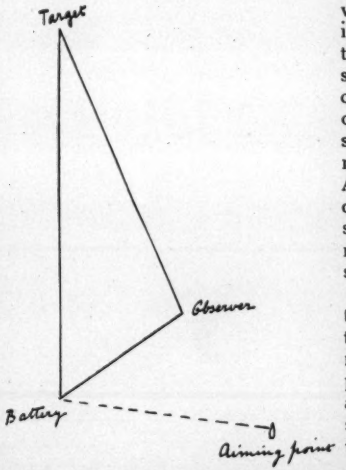


FIG. 1.

It may be necessary to switch the fire of the battery from one target to another one. There is not much difficulty in doing this, provided that the ranges and azimuth settings for the dial sights have been previously ascertained.

The above gives only a very elementary idea of the subject. Separate corrections for direction may have to be given for converging or diverging the fire, difference of level of the wheels of the gun carriage, etc.; and corrections for range due to the guns not all having the same muzzle velocity, etc. If the range found by the range finder is accurate, it does not follow that guns layed with it will range to the target. Allowances have to be made for temperature, barometer, wind, etc.

If the target can be seen by the guns, the procedure is much simplified, and it is necessary only to set the sight for the correct range and lay the sighting telescope or open sight on the target (Fig. 2). The angle of tangent elevation is the angle above the line of sight to the target at which the

axis of the gun must be layed in order that the shot may hit the target under normal atmospheric conditions. The angles for different ranges are ascertained by actual firing when a new pattern of gun is introduced. The trajectory, or path of the shot, is approximately a parabola, the angle of descent becoming steeper as the range increases.

Ordinarily, guns are layed for elevation or range by means of a spirit bubble, with what is known as quadrant elevation; the angle of quadrant elevation being the angle between the axis of the gun and the horizontal. If the gun and target are in the same horizontal plane, the quadrant elevation is the same as the tangent elevation; but, if the target is above or below the horizontal plane passing through the gun, the angles are not the same; the quadrant elevation being the tangent elevation plus or minus the angle of sight (*i.e.*, the angle between the line of sight from the gun to

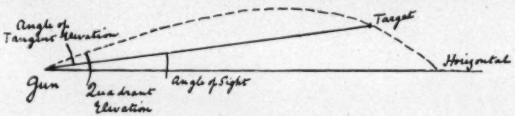


FIG. 2.

the target and the horizontal). Before laying with quadrant elevation, the angle of sight must be very carefully measured. Before laying the gun the spirit bubble is inclined to the axis of the gun at the angle of quadrant elevation. It is usually set in two steps, one being for the tangent elevation or range, and the other for the angle of sight. The gun is then elevated until the air bubble is in the centre of its run. When the gun has been fired, the distances over or under, right or left, of the target are estimated either by observation from suitable positions or by airmen, and the necessary corrections to the sighting arrangements are made.

The instruments used for observing the fire are usually telescopes, binoculars, or periscopes, fitted with graticules spaced at certain intervals, and sometimes of definite lengths.

II.

DESCRIPTION OF THE INSTRUMENTS.

Range Finder, 80 cm. base, made by Zeiss.

This is of the usual Zeiss pattern (see handbook of Artillery Instruments), but the following points are worth noticing:—The centre

of the range finder is in the form of a large ball (Fig. 3). This presumably fits in a socket at the top of the stand and allows for movement in all directions, but details of the top of the stand are not available.

The lower part of the stand consists of a very rigid wooden tripod about 33 ins. high. Attached to the top of each leg is a steel stamping in which

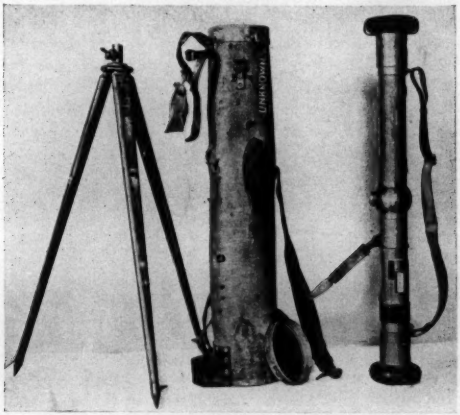


FIG. 3.—80 cm. Range Finder, Stand and Case (Zeiss).

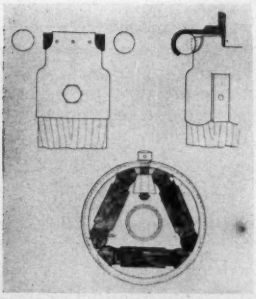


FIG. 4.—Details of Head of Stand. 80 cm. Range Finder (Zeiss).

is riveted a metal tube (Fig. 4). The ends of the tubes are shaped to take metal balls about half an inch in diameter. The balls, with the tubes between them, fit in a steel stamping which forms part of the top of the stand, in the same way that balls fit in a ball bearing. There are two balls between each two legs. Between two of the balls there is a steel wedge which can be moved radially in the ball bearing by means of a screw with capstan head, the screw passing through the side of the bearing. When the wedge is forced outwards by means of the screw, all the balls and heads of the legs are forced into close contact.

The result is that there is no play between the legs and the top of the stand, but the position of the legs can be adjusted with ease.

The lower part of the stand is strapped to the outside of the case.

The case is made of sheet tin or galvanized iron covered with canvas, and is remarkably light (weight, 5¼ lbs.).

Range Finder, 1¼ metre base, by Goerz. (*Sample not available.*)

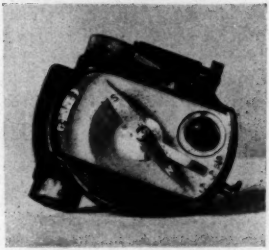
Magnification, 17.1 diameters.
Field of view, 2° 12′.
Width of central horizontal strip in field, 0° 10′.
Central strip inverted; lower edge used for ground targets, upper edge for aerial targets.
End prisms built up of mirrors silvered on the back.
Deflecting prisms similar to those in the Zeiss instrument.
Halving adjusted by two deflecting prisms working in opposite directions. Coincidence adjusted by deviating prism.
Fitted with self-containing adjusters, which are not accurate.
Centre prism combination different to Zeiss's combination.
Centre strip is in focus throughout its length.
Glass of objectives easily damaged by dilute nitric acid.
Eyepiece inclined at 30° to horizontal.
Weight, 33¼ lbs.
Overall length, 4 ft. 8½ ins.
Range scales to left of field of view, and 17 ins. to right of eyepiece.
Graduated to 15000 metres.

Stereoscopic Range Finders, by Zeiss. (*Sample not available.*)

The general principle of these range finders is as follows:—The body is a stereo-telescope with axes of the two arms rigidly fixed in prolongation with each other. In each eyepiece there is a scale of metres, the scales being slightly different from one another, and so arranged that the small marks near the figures appear to be at different distances from the observer. As objects seen through the range finder also appear to be at different distances from the observer (owing to the stereoscopic relief), it is only necessary when taking a range to note two consecutive graduations, one of which appears to be nearer, and the other farther away, than the target. The range of the target will be somewhere between the ranges indicated by these two graduations, and its exact range can be estimated.

These range finders cannot obtain ranges with anything like the accuracy of coincidence range finders, and very few people have sufficiently good stereoscopic vision to be able to use them. On the other hand ranges can be taken very rapidly with them, and they show up such objects as submarine periscopes which might not otherwise be noticed. It is easy to take a continuous record of the ranges of a rapidly moving

aerial target, as the latter appears to move to graduations which appear to be at the same distance as the target. They are also very useful for observing fire, as with them it can often be decided whether a shell bursts over or short of a target.



Compass with Telescope Removed.

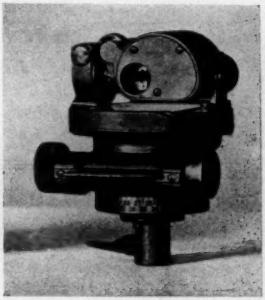


FIG. 5.

Director for Field Artillery (Zeiss).

Director for Field Artillery, by Zeiss.

The following are the principal data :—

Magnification, 3 diameters.
Field of view, 13 degrees.
Aperture of object glass, 0.5 in.
Diameter of emergent pencil, 0.166 in.
Weight of instrument without case, 2 lbs. 7½ oz.; with case, 3 lbs. 11½ oz.
" " stand " " 6 lbs. 10½ oz.
Length of " extended, 5 ft. 5 ins.
" " " closed, 3 ft. 1¼ ins.
Exterior dimensions of case for director, 5 × 5 × 6 ins.
" " " " " stand, 41 × 5 × 5 ins.
Optical qualities good over 9° of the field.

The instrument consists of the following parts:—A clamp by means of which it is attached to a pin at the top of the stand (Fig. 5). Attached to

the clamp is a graduated circle. This is divided into 64 parts, each division representing 100 millièmes (a millième is 3.375 minutes ; the tangent of 1 millième is approximately 1/1000). The scale is numbered from 0 to 32, and then again from 0 to 32 ; the slow motion micrometer has therefore to be graduated in one direction only. The remainder of the instrument revolves above the graduated plate. The slow motion gear is of the worm and worm wheel type, and is put out of action by pressing down a plate which rotates an eccentric. The " throw-in " is limited by a small stop screw, the amount of " throw-in " being sufficient to eliminate any backlash, but not enough to cause any binding. The micrometer head is graduated to read single millièmes, one turn representing 100 millièmes or about 5½ degrees. At the top of the body is a very large recess for a magnetic needle (about 3 ins. long) which can move through a complete circle. It is automatically kept off its pivot unless a spring push is pressed home. A circular spirit level is mounted inside the compass box. A small prismatic telescope is mounted on trunnions above the compass box. It can be elevated and depressed by means of a slow motion worm. A spirit bubble is rigidly attached to one side of the telescope body. The telescope is very compact, being only 2¼ ins. long. A glass diaphragm in the telescope has a vertical scale engraved on it (Fig. 6). The edge of the diaphragm away from the window is silvered to provide a good illumination for the scale. The scale is graduated upwards from 0 to 60. Each division represents approximately 10 minutes, actually $\frac{25}{16}$ of a degree, or 9.37 minutes. The 30 graduation will cut objects in the same horizontal plane as the director when the bubble is level. Angles of sight are measured by getting the bubble horizontal and noting which division cuts the target. There can be no error due to backlash, but only angles up to 300 minutes (or 5°) from the horizontal can be measured, except in relays. The object glass is a double achromatic lens and is mounted in eccentric rings so that the telescope can be collimated to the bubble. The eye lens combination consists of a triple field lens and a single eye lens. The optical performance is very good considering the very short focus of the object glass.

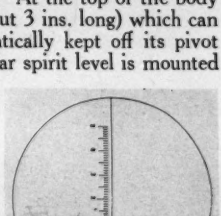


FIG. 6.—Graticule, Director for Field Artillery (Zeiss).

The stand is of the tripod pattern with brass telescopic legs, the upper parts of the legs fitting in the lower parts, so that mud, etc., cannot get between them (Fig. 7). At the top of the stand there is a neat ball and socket joint used for levelling. It is so constructed that during levelling the azimuth direction of the telescope does not alter. A slow motion

traversing gear is fitted immediately above the ball and socket. Above this is the pin to which the director is clamped.

Director for Heavy Artillery, made by Goerz.

The following are the principal particulars :—

Weight with case, 7 lbs. 3 oz.
„ without „ 4 lbs. 9 oz.
Overall dimension of case, $7\frac{1}{4} \times 6\frac{1}{2} \times 4\frac{1}{2}$ ins.

Telescope
- Magnification, 2 diameters.
- Field of view, 14 degrees.
- Effective aperture of object glass, 4 in.
- Eyepiece inclined to axis at 30 degrees.

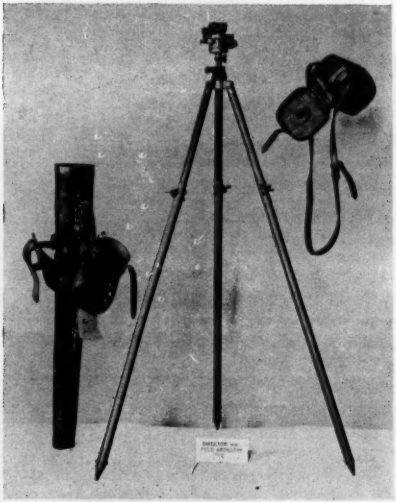


FIG. 7.—Director for Field Artillery on Stand, with Cases (Zeiss).

The director consists of two main parts, viz. :—

(1) The upper part with compass, protecting cap, circular level and centimetre scale (Fig. 8).

The compass needle is about $3\frac{1}{2}$ ins. long and is composed of two parts,

the lower one being a steel bar which projects well beneath the circular scale, and the upper one which is considerably shorter (Fig. 9). The latter is pointed, for reading the scale, and is apparently made of aluminium. Beneath the ends of the steel needle there is a copper ring, which has a damping action on the needle. The needle is put on or off its pivot by means of a bar, the ends of which project from each side of the case. When it is pushed in one direction it raises a small ivory

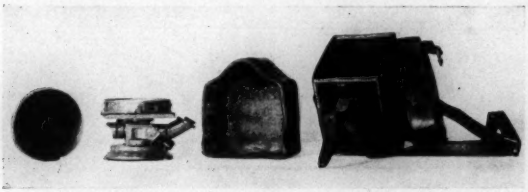


FIG. 8.—Director for Heavy Artillery, with Cases (Goerz).

stud which, acting on a spring, lifts the needle off its pivot. When it is pushed in the opposite direction the needle is lowered on to its pivot. If the needle is accidentally left on its pivot, it is automatically lifted off it when the cover is put on the compass. This is effected by the rim of the cover wedging one end of the bar away from the body.

A circular spirit level is mounted inside the compass box beneath the needle. The scale which is read by the compass needle is divided into 576 parts, each division representing ten sixteenths of a degree, or $37\frac{1}{2}$ minutes. Notches, for rough laying, are cut on the rim above the glass at N., S., E., and W. A centimetre scale reading in tenths of centimetres up to 9 centimetres is attached to one side of the compass.

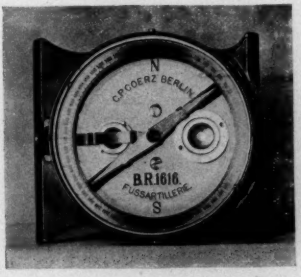


FIG. 9.—Compass. Director for Heavy Artillery (Goerz).

The base of this part of the instrument is flat, so that it may be laid upon a map or chart which can be measured and oriented by its means. The cover is of brass, and is attached by means of a bayonet joint.

(2) The lower part consists of a plate with azimuth scale and an upper plate which revolves upon it. To the latter are attached the telescope and a slide with catch for attaching the upper part.

The azimuth scale is engraved on German silver and is divided in the same way as the scale in the compass; but by means of a vernier and magnifying glass it can be read with 10 times the accuracy (*i.e.*, to about $3\frac{3}{4}$ minutes). The tangent of $3\frac{3}{4}$ minutes is almost exactly $\frac{1}{1000}$. The scale can be carefully set by means of a milled head and pinion on the right, and the plates can be clamped together by means of a milled head on the left.

The telescope is supported upon trunnions and has no elevating gear. One of the trunnions is in two parts, one of which is free to slide in the other but is held in register by a stiff spring washer. Any lateral wear is thus automatically taken up. There is a single vertical graticule in it. Attached to the telescope is an open sight for back laying.

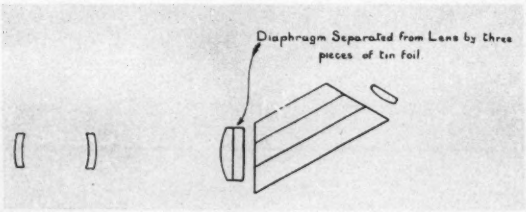


FIG. 10.—Optical System. Director for Heavy Artillery (Goerz).

The optical system (Fig. 10) consists of (1) an object glass, formed of two single meniscus lenses of 1 cm. aperture with a separation of nearly 2 cms., the concave faces being towards one another; (2) a single plano-convex collecting lens of 1.5 cms. aperture; a glass diaphragm across which is engraved a single line is placed adjacent to the plane surface, being separated by three pieces of tinfoil in order to prevent the formation of coloured rings; (3) a roof prism, in which the angles between the roof edge and the two ends faces are each 60°, and which bends the pencil of light upwards through an angle of 30° for convenience in observing; (4) a small plano-convex single eye lens which covers about one-half of the upper surface of the roof prism.

The case consists of two parts. The director is first put into a half case made of soft leather, and this is then inserted in the case proper. The latter is made of leather stiffened by some non-magnetic metal, probably zinc. It is very stiff.

Stand, probably for the Heavy Director.

The legs are telescopic, the lower portions being brass tubing about $\frac{3}{4}$ in. in diameter (Fig. 11). The upper portion of each leg consists of two pieces of wood ($26 \times \frac{1}{8} \times \frac{5}{16}$ ins.) rigidly connected together by two brass rings, and clamps at the lower and upper ends. The latter clamp is very ingenious (Fig. 12). It consists of a spindle, half of which is threaded right handed and the other half left handed. The screwed portions screw into two long screwed sockets which are attached to the wooden portion of the legs by means of screws. The wooden portions of

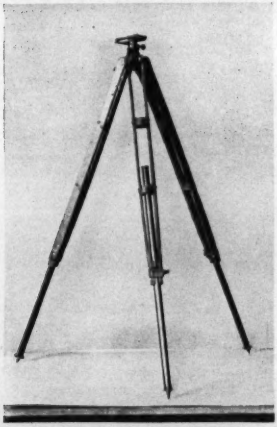


FIG. 11.—Stand, probably for Heavy Director.

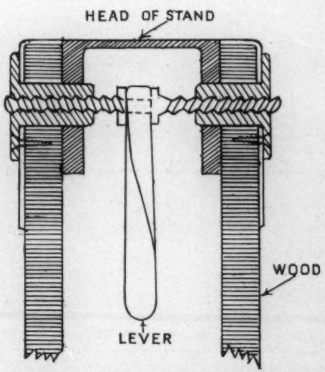


FIG. 12.—Details of Clamp. Stand, probably for Heavy Director.

the legs are in contact with flat bearing surfaces on the head of the stand. The screwed spindle can be revolved by means of a lever, about 2 ins. long, mounted centrally upon it. The lever is fitted over a hexagon and is forced against a rim on the latter by means of an adjusting nut.

When the lever is forced inwards, the wooden portions of the legs are forced away from the head of the stand, and the legs can be adjusted. When the lever is forced outwards the legs are clamped very firmly against the head of the stand. The head of the stand is provided with a ball and socket arrangement with clamp, an azimuth movement with clamp and a slide for taking the director.

The weight is 8 lbs. 10 ozs. Length, extended, 4 ft. 8 ins., and length, closed, 2 ft. 9 ins.

Stand, which is used with a Dial Sight as a Director.

The principal point of interest in this stand is the method of levelling the top of the stand (Figs. 13, 14). This is effected by means of four levelling screws which press against the four surfaces of a square beneath a ball, the latter being mounted in a socket. The dial sight is attached to a projection above the ball. A vertical feather-way cut in the ball and a screw passing through the cap of the socket prevent the ball moving in azimuth. This is probably a very good arrangement for levelling heavy instruments.

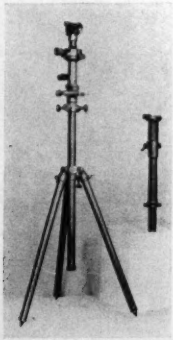


FIG. 13.—Dial Sight on Stand with 4 Levelling Screws.

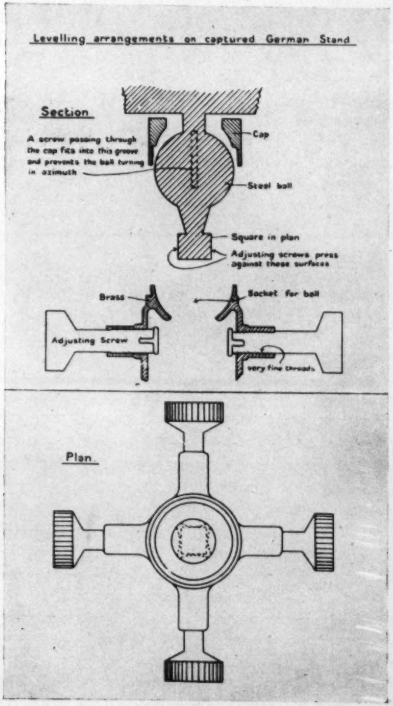


FIG. 14.

Dial Sights. Various patterns by different makers.

The general construction is similar to that of the No. 7 dial sight, the following being the principal points of difference :—

There is no open sight.

There is no dial plate, but a small German silver ring graduated in hundreds of millièmes. In some cases the drum is graduated from 0 to 64 ; in others, apparently of more recent pattern, from 0 to 32, and again from 0 to 32. In the latter case when the line of sight is directly to the front, the ring reads 16. There is only one micrometer drum graduated to read 100 single millièmes. In some cases there are additional figures, used apparently for putting on corrections. There is no reader bracket or adjustable reader. The reader is a fixed mark on the central pillar, but the small dial ring is adjustable. It has four elongated holes ; an outer ring is fitted over these holes, and has four countersunk holes in it, through which pass the screws for clamping the ring.

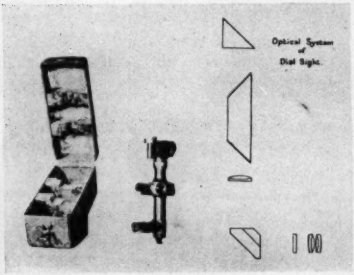


FIG. 15.—Dial Sight.

The method of attachment to the carrier is different. The coned seating is the same, but instead of a nut at the bottom of the " pillar supporting " there is a hook. This engages with a grooved bar in the carrier. When the latter is revolved by means of a lever, the sight is either drawn firmly down on to the carrier, or it is slightly raised from it.

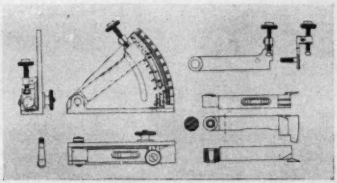


FIG. 16.—Clinometer (R. Stock & Co.).

All the parts are made of steel. The worm wheel and upper bevel wheel are in one piece, made from the solid bar. Both worm wheel and spindle are of a very high grade carbon steel with percentage carbon content of about 0.8.

The sight is carried in a strong iron box with wood fittings (Fig. 15).

Clinometer, made by R. Stock & Co.

It is apparently made of plated brass or gunmetal, with the exception of the steel pivot and the slow motion adjusting screw.

The base is about $4\frac{1}{4} \times \frac{7}{8}$ ins. From one side of the base extends a vertical arc, graduated from 0° to 50° and also with two range scales (Fig. 16).

The bubble arm is pivoted at one end of the base. On the same pivot is mounted a flat plate, on a projection from which there is a split screwed

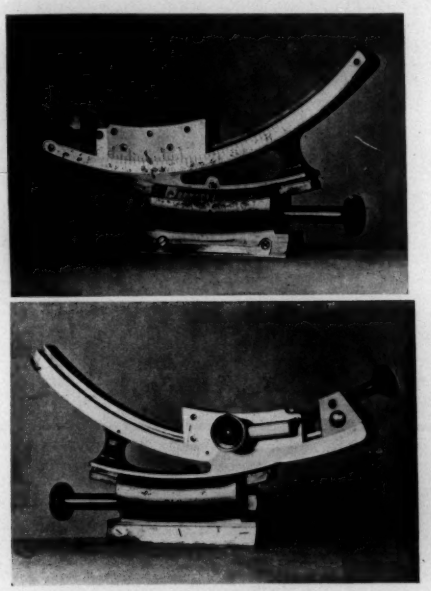


FIG. 17.—Sight Clinometer.

socket for the bulb-shaped end of the fine adjustment screw. At the back of the plate is a screw with nut which passes through a curved slot in the vertical arc. By means of this nut the flat plate can be clamped to the arc, and by means of the slow motion screw, which engages in the top of the bubble arm, the arm may be accurately set to the required elevation. At the end of the bubble arm is a vernier, by means of which the degree scale can be read to sixteenths of a degree. The lower edge of the

vernier plate is used for reading the two range scales. The bubble is sensitive to a movement of 15 seconds, and moves one division with a tilt of 1 minute. There is no apparent means of adjusting it. The maximum elevation that can be given by the clinometer is about 42°.

A very strong wooden box is supplied. The weight of the clinometer in its box is 1 lb. 5 oz., and the exterior dimensions of the box are about $4\frac{1}{2}$ ins. (at the broadest end) $\times 5\frac{1}{2} \times 1\frac{1}{2}$ ins.

Sight Clinometer.

This is an instrument for laying guns with quadrant elevation, and consists mainly of three carriers which slide one upon the other in arc bearings, the upper carrier being fitted with a bubble (Fig. 17). It can be set for three different purposes, viz. :—

(1) For angle of sight, on the lower scale. This is set by means of a worm.

(2) For tangent elevation, either in degrees (with a vernier to read sixteenths of a degree) or by means of range scales for shell or for shrapnel.

This is set by means of a screw which passes through a clamp and is attached to one end of the central carrier. A quick setting can be made by loosening the clamp and sliding the carrier along its arc.

(3) For correcting the fire. This is set by turning a milled head which slides the upper carrier containing the bubble along its arc. It is provided with a "clicker" which consists of a toothed wheel on the main spindle and a spring plunger which engages between the teeth on the wheel. Each time that the gear clicks a definite correction is put on.

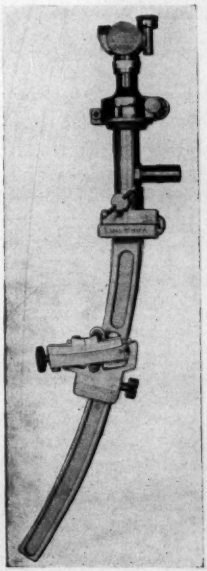


FIG. 18.—Sighting Arc for Field Guns.

The principal points of interest are :—Metal parts plated. Scales, readers and worm arcs made separately and let in. Steel bearing to side of slide. Good protection of the bubble. Use of sheepskin with wool for lining the case.

Sighting Arc for Field Guns.

The principal points of interest are as follows :

Instead of a rocking bar, the sight consists of a steel arc which slides in a curved bearing (Fig. 18). It is raised or lowered by means of a wheel having a spiral cut on one of its flat faces. The spiral engages with teeth on one side of the arc. The teeth are not cut in the arc, but on a separate plate which is dovetailed in the arc.

The dial sight carrier is attached to the top of the arc.

The sight clinometer is rather complicated and consists of arcs which slide along one another. The opening in the bubble casing is not immediately above the centre of the bubble, but rather to one side, so that it is not necessary to view the air bubble from a point vertically above it.

The threads of the worm spindles and the teeth of the worm arcs are *very* deeply cut, consequently there can be no quick motion. End play of the worm spindles is taken up by means of spiral springs inserted between the thread of the worm and one of the end bearing pieces. One of the worms is cone shaped.

There are lubricating holes in several of the worm spindle bearings. A very compact form of collimator, or open sight, is provided (see inset, Fig. 18). The dimensions of the glass portion are only $2\frac{1}{2} \times \frac{3}{8} \times \frac{1}{4}$ ins. It consists of one piece of glass, one end of which is suitably curved so that the other end is exactly in focus. This end is silvered and blacked, and two lines, meeting at the top centre, are cut in the black for use as a sighting mark. The four sides of the glass are blacked to prevent internal reflections.

Such a collimator is a very efficient form of view finder, as the lines in it always appear to be at infinite focus ; and both they and the target appear to be in correct focus. The lines and the target appear to almost overlap one another, even if there is a fairly thick mount above the collimator glass.

Sighting Arc for Heavy Guns.

This consists of a steel arc at the top of which is fixed a dial sight somewhat similar to the heavy director, except that it has no compass (Fig. 19). The arc is graduated in degrees up to 42° and in metres up to 7450. There are no fewer than 7 separate scales.

The dial plate is divided into 576 divisions (each being $\frac{10'}{16}$), and can be read to $\frac{1}{10}$th of a division by means of a vernier and magnifying glass. Independent corrections can be put on by means of a small spindle with milled head. This is provided with a spring " clicker," each click representing a definite correction.

The telescope is rigidly fixed and cannot be elevated. A circular bubble is fixed on the top of it.

The telescope has a magnification of 1½ diameters and a field of view of 22½ degrees. The eyepiece is inclined to the axis at 66°.

Stereoscopic Telescope, made by Zeiss.

Principal details are :—

Magnification, 10 diameters.
Field of view, 4° 12′.
Diameter of object glass, 1.8 ins.
Diameter of emergent pencil, 0.18 in.
Optical properties good.
Distance between centres of prisms when arms are extended, 27¼ ins.
Weight without case, but including elevating gear, 10 lbs. 14 ozs.
Weight of case, 6 lbs.

The design is generally similar to the service one, the principal points of difference being as follows :—

(1) The prisms forming the eyepiece combination are not balsamed together, but are held separately by clips. The larger of the two prisms is tilted by a thin slip of wood placed under it, and a piece of paper packing is placed under the smaller prism. This is probably for the purpose of obtaining an additional adjustment for parallelism.

(2) The upper prism is mounted in an inner aluminium housing. Two screws, to which are attached circular bearing pieces, hold it on either side in the right-angle corner. The prism is further secured and kept in position against the two bearing faces by means of two metal wedges on each side, which are slipped between the prism and its mount and are held in position by small screws.

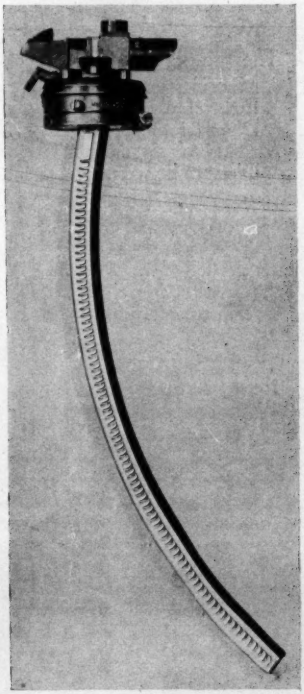


FIG. 19.—Sighting Arc for Heavy Guns.

(3) In the front of the hood is a recess in which is inserted a thin wedge-shaped packing piece, which thus comes between the hood and the prism mount. This is apparently used for uprighting the image.

Stereoscopic Telescope, by Goerz.

The principal details are :—

Magnification, 10 diameters.
Field of view, 5° 15′.
Diameter of object glass, 1.75 ins.
„ „ emergent pencil, 0.175 ins.
Distance between centres of prisms when arms are extended, 27¼ ins.

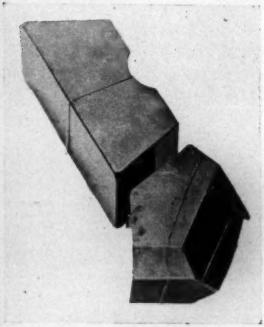
It will be noticed that the diameter of the apparent field of view is about 25 per cent. greater than that of the Zeiss or service pattern telescopes. The upper prisms are each mounted on a substantial aluminium casting, the lower portion of which is threaded internally to receive the end of the body. The prism rests on a flat bearing with a circular aperture ; a rectangular groove is cut along each side of the prism, into each of which fits a clamping piece which is screwed to the mount. Strips of cardboard are inserted to take up shock. Two bearing pieces are also screwed to the mount in front of and behind the prism, to prevent any forward or backward movement ; but these bearing pieces do not bear directly on the glass, thin strips of cardboard being inserted as shock absorbers. The prism is thus held securely and at its strongest part, the risk of fracture being reduced to a minimum. An aluminium casting, with a glass window, fits over the prism and is screwed to the prism mount. The prism does not touch its housing anywhere (Fig. 20).

FIG. 20.—Stereoscopic Telescope with Case (Goerz).

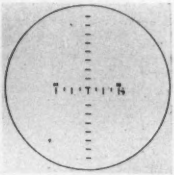
This upper portion is screwed over the end of the body and secured by 10 screws, which for greater

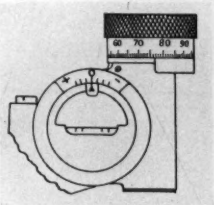
security screw into a split steel ring inside the body. A cover ring is then placed over the exposed portion of the prism mount to cover up the screw threads. To ensure watertightness the various parts are luted together with a compound resembling Chatterton.

The lower prism system consists of two prisms (Fig. 21). The two smaller polished faces of the first prism are inclined to the long face at angles of $67\frac{1}{2}°$. The second prism has two rectangular polished faces inclined at an angle of 45°, and two roof faces meeting in an edge making angles of $22\frac{1}{2}°$ with the other faces. The central ray enters the first prism and emerges from the second prism normally. This arrangement of the prisms has the advantage of compactness and enables a pleasing outline to be given to the instrument, although it is somewhat complicated in manufacture.



Horizontal Division = $\frac{5}{16}$ Degree.
Vertical Division = 5 Milliemes.





Lower Prism System. Graticule. Angle of Sight Level.

FIG. 21.—Stereoscopic Telescope (Goerz).

The first prism is mounted in an aluminium frame fixed into the body by three screws ; the holes in this frame are slotted to allow for adjustment of the prism to secure uprightness and parallelism. The roof prism is held at the sides by two circular plates fixed into the body, and has bearings for its front and roof faces. A plate, recessed into the body, luted round and screwed in, covers the prisms and can be removed if adjustment of the prisms is necessary.

The object glass is mounted in an aluminium cell and is secured by a screwed counter ring, slotted to give spring and having three small bearing faces to hold the object glass with the minimum liability to distortion. The object glass screws into a brass collar in the body.

The interior of the body is painted with a hard dulled grey paint ; the exterior is also painted grey with a rough surface.

The right eyepiece contains a graticule, the horizontal and vertical intervals being respectively $\frac{5}{16}$ of a degree and 5 millièmes (Fig. 21). The graticule is fixed in a revolving ring so that its orientation can be adjusted to suit the extension of the telescope arms. The diaphragm window is of red glass. The eyepieces are screwed into brass bushes let into the body.

An elevating gear is provided by means of which the telescope may be used for measuring angles of sight. The worm spindle has at one

FIG. 22.—Artillery Periscopes, with Cases (Goerz).

end a ball and socket bearing. The bearing for the other end is held at the sides by two screws, while a spring presses on its upper surface to keep the worm well into gear and avoid backlash. The teeth on the worm and arc are deeply cut, but might with advantage be stronger in view of the heavy strain on them when the telescope is elevated. The angle of sight is measured by a small clinometer consisting of a bubble mounted in a circular frame on the outside of which teeth are cut. Into

these engages a small worm spindle to which is fitted a micrometer head (Fig. 21). Angles of elevation or depression up to 19° can be measured. The clinometer is compactly placed between the two arms, above the elevating gear worm spindle.

The telescope can be clamped at any extension by means of a clamp consisting of a number of small steel plates, alternate plates being secured to the ends of the two bodies respectively.

The telescope can be used directly on a stand, or if azimuth angles are required to be measured, an attachment is provided for inserting between the telescope and stand. The stand is a steel tripod with telescopic legs, the upper portions sliding into the lower ones. The upper parts have a very good black finish. A ball and socket joint is provided at the top, and the pin for taking the telescope is plated.

Two-power Artillery Periscope, made by Goerz.

The principal details are :—

	Low power.	High power.
Magnification,	10 diameters.	15 diameters.
Field of view,	4°	2° 40′.
Apparent field,	40°	40°.
Diameter of emergent pencil,	.15 ins.	.10 ins.

Aperture of object glass, 1.5 ins.
Distance between centres of upper and lower prisms is half a metre.
Weight, without case, but including rainguard, 6 lbs.

The design of the periscope differs from that of the majority of small high-power periscopes in that a telescope system is used and not a prismatic binocular system. This has the advantage of making the periscope compact in shape, by eliminating the projecting prism box, and although the length is as a result somewhat increased, this is not without advantage for an artillery periscope (Fig. 22).

The upper prism box is a light gunmetal casting ribbed for strength on the inside of the hypotenuse face. The prism takes a bearing on its lower face and at the bottom of its front face against a ledge made for the purpose in the casting. The prism is held on each side by a small circular plate attached to a screw passing through the side of the casting ; these plates hold the prism at its strongest parts. An aluminium plate presses against the back of the prism, bearing on the prism at its edge only ; this plate is held in contact with the prism by the pressure of three screws passing through the hypotenuse surface of the prism cover. The advantage of this method of holding the prism is that the risk of its being injured if the cover receives a blow is reduced to a minimum. The front of the prism box is closed by a plate in which is mounted a

circular glass window. The plate and window are luted round to ensure watertightness.

A rainguard $7\frac{3}{4}$ ins. long, is attached to the upper prism box by two swivel spring straps; when in use, it is held in position by a bayonet catch; when not in use it is sprung round the body of the periscope.

The body is of steel; in it are mounted the object glass and the erecting system. The object glass is a cemented achromatic doublet of 8 in. focal length. The erecting system consists of two equal achromatic lenses of aperture 0.75 in. and focal length 4.13 ins., separated by a spring washer 0.25 ins. long. The two lenses and washer are mounted in one tube and secured by a counter screw. The interior of the body is painted with a dull grey adherent paint.

Optical Section.

FIG. 23.—Artillery Periscope (Goerz).

The lower portion of the periscope is fixed to the body by three screws screwing into projecting lugs on a collar attached to the body. The lower prism is a single right-angled prism (Fig. 23). The two focussing eyepieces, giving powers of 10 and 15 diameters respectively, are similar to the focussing eyepieces of prismatic binoculars. The periscope has no graticules. The eyepieces screw into a sleeve which can be revolved to bring either eyepiece as required opposite the lower prism.

The lower prism box has a socket attached to it for fitting to a pivot on a stand. Leather caps attached to small projecting lugs are provided for covering the eyepieces and upper window when the periscope is not in use.

The case is made of sheet iron covered with canvas and well padded internally at the top and bottom with felt and with a soft band about 2 ins. wide for the eyepieces to rest against.

Long Periscope, by Goerz.

This is generally similar in design to the short one made by the same firm (Fig. 22).

The following are the principal data :—

	Low power.	High power.
Magnification,	10 diameters	15 diameters.
Field of view,	4°	2° 45′.
Apparent field,	40°	41° 15′.
Diameter of emergent pencil,	.18 in.	.12 in.

Diameter of object glass, 1.8 ins.
Definition and colour correction are inferior.
Brilliancy is fair.
Distance between centres of prism, 1 metre.
Weight without case, 7 lbs. 15 ozs.

Galilean Binocular, made by Emil Busch.

The following are the principal particulars :—

Magnification, 5.5 diameters.
Field of view, 3 degrees.
Aperture of object glass, 1.5 ins.
Weight without case, 1 lb. 5 ozs.
Length at normal focus, 4.6 ins.
The object glass is a doublet and the eye lens a single lens.
They are mounted in brass cells.
Optical qualities fair.

Each body is an aluminium casting, the hinge leaves and loops for neck sling forming part of the castings. The bodies are coated with a dull adherent paint, possibly mixed with sand or oatmeal, so as to form a rough surface.

Each eyepiece can be focussed and is provided with a diopter scale reading from − 10 to + 10. The hinges are provided with a clamp and an interocular distance scale.

A rainguard is attached to the neck sling, along which it can slide, its object being to protect the eyepieces from rain when the binocular is not being used. A flap to attach to a button of the user's coat is fixed to the front hinge. This prevents the binocular swinging about when it is being carried by means of the neck sling.

All joints in the binocular are well greased and the binocular should be watertight.

Sighting Telescope for Machine Gun, made by Busch.

The following are the principal data :—

Magnification, 2.5 diameters.
Field of view, 11 degrees.
Effective diameter of object glass, .7 in.
Weight complete in case, 3 lbs. 4 ozs.
External dimensions of case, 7.4 × 6.7 × 2.5 ins.
The definition and brilliancy are very good.
There is no focussing arrangement, and the telescope should be practically airtight (Fig. 24).

The optical arrangements are very beautiful in design and manufacture. They are very strong and should never get out of order. They consist of :—

(1) The object glass.

(2) A large prism—which has four reflecting surfaces, two of which are on the roof portion (Fig. 25). Reflection at these surfaces neutralises the inverting effect of the object glass. A large recess fits over a support inside the telescope which affords a very firm bearing for the prism. The latter is kept from moving sideways by means of a spring.

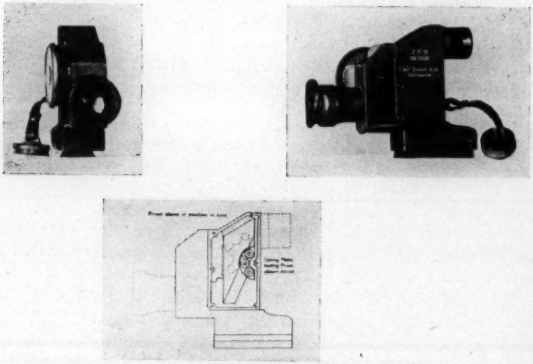
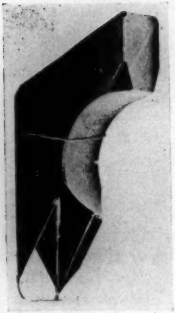


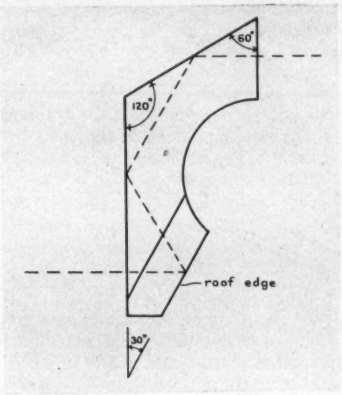
FIG. 24.—Sighting Telescope for Machine Gun (Busch).

(3) The diaphragm has mounted on it two radial wires which meet at the optical centre. It is moved up or down in a slide by means of an eccentric actuated by the range drum. The latter is graduated from 400 to 2000 metres, the graduations being filled in with a white metal on a black background (Fig. 25).

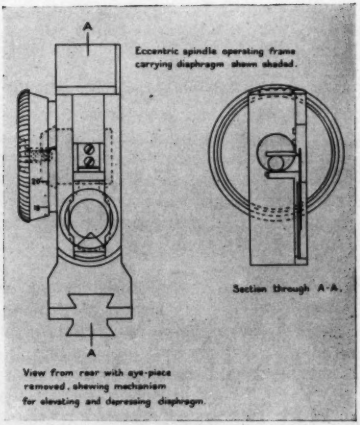
(4) The eyepiece, which consists of two lenses.

Owing to the axis of the object glass being about 2 in. higher than that of the eyepiece, the layer is protected to a certain extent by his steel helmet and the gun. Two anti-glare glasses are provided. One is of light yellow and the other of medium fieuzal tint. They fit over the object glass.





Prism.


A
Eccentric spindle operating frame carrying diaphragm shown shaded.
Section through A-A.
A
View from rear with eye-piece removed, shewing mechanism for elevating and depressing diaphragm.

Diaphragm.

FIG. 25.—Sighting Telescope for Machine Gun (Busch).

A metal protecting cap for the object glass is attached to the sight by means of a strap.

The care with which the steel slide (for attachment to the gun) is fitted is noticeable. Instead of being merely screwed on to the aluminium body, it is dovetailed into it, and then secured by screws. There is a leather eyeguard on the eyepiece.

The case has loops to fit on the waist belt.

The lid opens away from the wearer's body and can hang down freely. In it are two compartments for the anti-glare glasses which are kept in position by leather flaps with glove fasteners.

III.

All the instruments appear to have been very carefully thought out and designed. They are constructed in such a way that they are not likely to get damaged, and at the same time are not too bulky or heavy. There are as few projecting parts as possible. They are made as fool-proof as possible. The standard of the workmanship is very high, and they are mostly produced by firms of world-wide repute.

The cases are nearly always made of sheet iron covered with canvas, except when the instruments have compasses, when non-magnetic metals, *e.g.*, zinc, are used. As a rule there is plenty of space between the instrument and the sides of the case, so that, if the latter become dented, the instrument will not be damaged.

The external finish affords very good protection, is thoroughly adherent and inconspicuous. Bronzing and lacquering does not appear to be used. As a rule the instruments are covered with a very tough enamel which has evidently been well stoved. In some cases the enamel has a rough surface, which, I understand, is obtained by mixing oatmeal with it. Many small parts are plated. Frequently a final coating of paint is applied after assembling, so covering over the heads of all screws and assisting in rendering the instruments waterproof. Mechanical working parts are usually well covered in.

Internally the instruments are very clean, great care having been taken to clean the glass and other parts before assembling them. Optical black does not appear to be used. The interiors of some instruments appear to be painted with a fairly dull grey paint. Efficient stopping is relied upon for cutting out internally reflected light.

All the instruments which contain prisms are practically airtight, the joints (even those which are screwed together) being effectively filled in with a material resembling mastic.

The instruments are sometimes very difficult to take to pieces, and the number of small screws is remarkable.

Some of the prisms are very ingeniously and effectively mounted, but the adjustment of others appear to be carried out by packing under them with bits of cork, paper, etc.

Some of the prisms appear to be rather complicated, and there are many examples of roof prisms. A single prism with four reflecting surfaces is less liable to get out of adjustment than two double reflecting prisms. Also it is probably easier to mount. It appears to me that British manufacturers must make up their minds to manufacture complex prisms for military instruments.

The balsaming together of prisms appears to be done in a very thorough manner. Instead of merely balsaming two faces together, a small groove is cut round the outside edge of the prisms where they meet. This is filled with balsam, and more balsam is applied over this. The balsam is well baked and very hard.

The magnification of the small telescopes on directors, sights, etc., varies from about $1\frac{1}{2}$ to 4 diameters. None of them have any focussing arrangement. This is advantageous for rendering the instruments airtight. That of observing telescopes, *e.g.*, stereoscopic telescopes, periscopes, etc., varies from about 10 to 15 diameters.

Arrangements for preventing rain settling on the object glasses of telescopes are nearly always fitted.

The use of small telescopes on directors, which apparently are not used for observing fire, enables the body of the director to be made comparatively small.

Directors are fitted with compass needles at least 3 ins. long.

The stands are extraordinarily light and rigid, and have a ball and socket joint by means of which the instrument can be levelled without the legs being moved.

It is not known if straight telescopes have been entirely superseded by periscopes and stereoscopic telescopes which allow of observations being made from under cover, but there is reason to believe that such is the case.

Very many useful hints may be picked up from detailed examination of the instruments, and applied to instruments which may be required by this country in the future. The designing of instruments in this country appears to require the most careful consideration. The principal needs appear to me to be as follows :—

(1) That designers should be thoroughly acquainted with the uses of military instruments.

(2) That designers should be familiar with all existing designs.

(3) That all designers of repute should be asked to submit designs when a new instrument is required.

DISCUSSION.

The PRESIDENT said that, by the courtesy of Lieut.-Commander Wimperis, he was able to exhibit a Bomb-dropping Sight which was rescued from the ruins of a Zeppelin brought down near Salonika. It consisted of a short telescope mounted on gimbals. In front of the object glass there was a roof prism system which served to invert the image and to deflect the rays through 15°. In the field of view there were two cross-wires at right angles to a central wire in the fore-and-aft line of the airship. The distance between the cross-wires was adjusted so that, if a bomb were released when an object was on the first cross-wire, it would hit the object and the burst would be seen on the second cross-wire. This was done by making barometric measurements of the height of the Zeppelin, and observing the time of passage from one cross-wire to the other of the image of an object on the ground, by means of a stop-watch attached to the instrument, the ground speed of the Zeppelin being thus determined. If, when the adjustments were made on the scales of the instrument, the burst of the first bomb were seen a little before or behind the second cross-wire, the necessary correction could be made for the next shot.

Dr. A. BARR said we should be foolish if we did not learn all we could about tactics and equipment from the enemy. He was certain that Col. Williams did not intend us to assume that the special features in the German instruments were entirely due to the firms using them, for many of these features were not of German origin. The use of two mirrors instead of a solid prism in range-finders was, he thought, at least one hundred years old. The dial sight system was due to Sir Howard Grubb, and had been taken by the Germans from one of the Grubb patents. The little finder was of French origin; it was known as the Raguet finder, named after an officer in the French army. The roof prism system was Italian. He thought, however, that the ideas had been well worked out and the instruments were beautifully constructed.

Mr. J. W. FRENCH said the Society had been given a unique opportunity of seeing German instruments of the war period. Some of those exhibited he had seen in 1913, when they were regarded as strictly confidential. The German Government had not adopted certain of the range-finders shown until just before the war. He believed that the bulk of the range-finders used by the Germans were made by the firm of Hahn, which had succeeded in making an instrument that did not break (in certain Turkish tests) when dropped from a height of 6 ft. over a fallen tree. As the result of continuous trials of range-finders on the

Continent about four years before the war, the Allied firms had been very successful. The German Government had then specified the Barr & Stroud patents, and the German firms thought the best way was to appropriate the patents. As the result of an action in the Supreme Court at Leipsig in July, 1913, the British patents had been upheld.

Many of the instruments shown contained most beautiful features, but he thought that the majority of them, particularly those designed by Goerz, were too intensely designed. Possibly it was to the interest of great firms such as Goerz and Zeiss to design instruments which other firms could not easily make.

Dr. Barr had referred to the various prisms exhibited. It was difficult to say who invented this or that prism. Some of the prisms, such as the roof prism, were described with great precision in a book by Baptista Porta, written in the year 1644. The pentagonal prism, called by the Germans the Prandtl prism, was first mentioned, he thought, by a French artillery officer, called Goulier. The Stanhope finder, or collimator, exhibited had been very well known in this country for many years before the war. The French Government had used large ones, called Raguet finders, made up in several parts to compensate for distortion. His firm had made large numbers of the smaller ones.

He would like to ask Col. Williams about the weight of the instruments. The Army was always anxious to make things as light as possible, but his impression was that the question of lightness had been sacrificed by the German Army, at least in range-finders. He would also like to know if it was the German practice to use steel tubes, reinforced with wood, for the tripod legs.

He had been much interested in the bomb-dropper. He understood that the Germans did not rely on such complicated apparatus at high elevations, but that they dropped the bombs and trusted to Providence.

Mr. Conrad Beck said that before the war optical manufacturers had had great difficulty in obtaining information about foreign instruments. He could not agree with Mr. French that the design of the dial sight was too complicated. After the experience his firm had had of making thousands of these sights, he would take off his hat to the man who first designed the dial sight. At first sight it might seem that the instrument was too complicated, but one found ultimately that there was reason for the various elaborations. He thought the stand shown was very prettily designed. He considered that we could learn little from Germany as regards invention, in which they did not excel, but the manner in which their details were worked out would repay careful study by the British optical instrument makers.

AUTHOR'S REPLY.

Col. WILLIAMS, in reply, said he entirely agreed with Dr. Barr's remarks, and he was sorry if he had said anything which might give a false impression as to the origin of the prisms and mirrors. As regards Mr. French, he was not sure about the Raguet and the German collimator. He thought the former was always made of two pieces of glass to get rid of chromatic errors, whereas the German collimator was only made of one piece.

Mr. FRENCH, interposing, said the original Raguet, known as the Stanhope finder, was made of one piece.

Col. WILLIAMS, continuing, said that for ordinary view finders the German pattern was quite large enough. He thought that on the whole the German instruments were somewhat lighter than ours, and they were certainly a good deal less bulky. With reference to the stands, they were made of brass if the instrument contained a compass, and of steel if there was no compass. The lower parts of the legs were, of course, hollow, and, as far as he knew, the upper parts were also hollow. The stand with the four levelling screws was an exceptional one. The ordinary stand had telescopic legs with a ball and socket joint at the top, and a slow motion traversing gear.

Mr. T. SMITH asked whether the Germans had reduced the dimensions of the instruments to such an extent that the light transmission had been diminished.

Col. WILLIAMS said he had not found that to be the case with the instruments in question. The magnification was not greater than 4 in the small instruments, or than 15 in the stereo-telescopes and telescopes. He thought the exit pupil was in every case adequate.

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